1 a) DC-DC Buck Voltage Converter
CSSL-IV Program Listing

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PROGRAM ADEM
" DC-DC Buck Converter Model "
" Technical Consultant: Dr. Alfred Barrett, Phone:(765) 451-3830 "
" Delphi Energenix Center, Kokomo,IN "
" Program Consultant: Dr. Yilmaz Sahinkaya, Phone:(650) 574-0254 "
" SMA, Inc., San Jose, CA "
" Model Creation Date: October 11, 1999 "
                    " Units : Metric "
                    " System Parameters "
" General Parameters"
" TFIN = Simulation Time (sec) "
CONSTANT TFIN = 500.0E-6          $" 500 micro-seconds "
" TS1  = Simulation Starting Time (sec) "
CONSTANT TS1  = 10.0E-6
" Buck Converter Parameters "
" Control Parameters "
" FPWM = Pulse Width Modulation (PWM) Frequency (Hz) "
CONSTANT FPWM = 500.0E+3          $" 500 KHz "
" DCYCLE = Duty Cycle ( fraction, range: 0.0-1.0 ) "
CONSTANT DCYCLE = 0.338
" V1    = Input Voltage (Volts) "
CONSTANT V1IN   = 42.0
" ILOAD = Load Demand Current (Amperes) "
CONSTANT ILOAD = 0.0
" IDISCH, IHKEEP = Current Losses (Amperes)"
CONSTANT IDISCH 0.400, IHKEEP = 1.09
" Circuit Parameters "
" R3 = Transistor 3 ON Resistance (Ohm) "
CONSTANT R3 = 2.0E-3
" Input Filter "
" R30 = Resistance(Ohm), C30 = Capacitance (Farad) "
CONSTANT R30 = 50.0E-3, C30 = 20.0E-6
" Output Filter "
" L45=Inductance(Henry),R50=Resistance(Ohm), C50=Capacitance(Farad)"
CONSTANT L45 = 2.0E-6, R50 = 50.0E-3, C50 = 50.0E-6
" R52 = Output Resistance (Ohm) "
CONSTANT R52 = 13.4E-3
" Given Initial Conditions "
CONSTANT IL45Z=0.0, VC30Z = 0.0, VC50Z = 0.0
                    " Initial Region Computations "
INITIAL
" TPER = PWM Switching Period (sec) "
TPER    = (1.0/FPWM)
" TPW1 = Transistor 1 ON Time or Pulse Width (sec) "
TPW1    = (DCYCLE*TPER)
" TPW2 = Transistor 1 OFF Time (sec) "
" TPW2 = Transistor 2 ON Time (sec) for Synchronous Rectification "
TPW2    = (1.0-DCYCLE)* TPER
" TS2  = Starting Time for Transistor 2 Pulse (sec) "
TS2     = TS1+TPW1
" Initialization of State Variables for Steady-State Operation "
END INITIAL
                    " Dynamic and Derivative Region Computations "
 DYNAMIC
  DERIVATIVE EQS
                    " Simulation Controls "
  ALGORITHM ISTART = 5, IRUN = 5
  CINTERVAL CI     = 0.5E-6
  NSTEPS    NST    = 200
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                    " V1    = Input Voltage "
  V1      =  V1IN*STEP(TS1,T)
                    " IRS3 = Current Through Transistor 3 (Amperes) "
  IR3     = (V1-V3)/R3
                    " IR52 = Load Demand Current "
  IR52    =  ILOAD*STEP(TS1,T)
                    " DC to DC Buck Converter Operation "
  " SW1, SW2 = Transistors 1 and 2 Swithing Commands "
  SW1     = PULSE( TS1, TPER, TPW1, T )
  SW2     = PULSE( TS2, TPER, TPW2, T )
  PROCEDURAL (IL45S, SWMODE = T, SW1, SW2, V3, V5 )
    IF(T.LT.TS1)        THEN
      IL45S    = 0.0
      SWMODE   = 1.0
    ELSEIF(T.GE.TS1.AND.(SW1.GT.0.5).AND.(SW2.LT.0.5)) THEN
      IL45S    = (1.0/L45)*(V3-V5)
      SWMODE   = 1.0
    ELSEIF(T.GE.TS1.AND.(SW1.LT.0.5).AND.(SW2.GT.0.5)) THEN
      IL45S    = -(1.0/L45)*V5
      SWMODE   = 0.0
    ENDIF
  END
  IL45    = INTEG(IL45S,IL45Z)
  IC30    = (R3/(R3+R30))*(((V1-VC30)/R3)-IDISCH-IL45*SWMODE )
  IC50    = IL45-IHKEEP-IR52
  VC30S   = (1.0/C30)*IC30
  VC30    = INTEG(VC30S,VC30Z)
  V3      = VC30+IC30*R30
  VC50S   = (1.0/C50)*IC50
  VC50    = INTEG(VC50S,VC50Z)
  V5      = VC50+IC50*R50
  V2      = V5-IR52*R52
          " Power Computations "
  " PWOUT = Power Output (Watts) "
  PWOUT = V2*IR52
  " PWLOSS  = Power Losses (Watts) "
  PWLOSS= V3*IDISCH + V5*IHKEEP + R52*IR52**2
  " PWIN = Power Input (Watts) "
  PWIN  = PWOUT +PWLOSS
  END DERIVATIVE
 TERMT(T.GE.TFIN)
 END DYNAMIC
                          " Terminal Region Computations "  "
 TERMINAL
 END TERMINAL
END PROGRAM
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Figure 5. CSSL-IV Program for the DC-DC Buck Converter

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PROGRAM ADEM
" Approximate DC-DC Buck Converter Model "
" Technical Consultant: Dr. Alfred Barrett, Phone:(765) 451-3830 "
" Delphi Energenix Center, Kokomo,IN "
" Program Consultant: Dr. Yilmaz Sahinkaya, Phone:(650) 574-0254 "
" SMA, Inc., San Jose, CA "
" Model Creation Date: December 12, 1999 "
                  " Units : Metric "
                  " System Parameters "
" General Parameters"
" TFIN = Simulation Time (sec) "
CONSTANT TFIN = 1.0E-3        $" 1 milli-seconds "
" TS1  = Simulation Starting Time (sec) "
CONSTANT TS1  = 10.0E-6
" Buck Converter Parameters "
" Control Parameters "
" FPWM = Pulse Width Modulation (PWM) Frequency (Hz) "
CONSTANT FPWM = 500.0E+3        $" 500 KHz "
" DCYCLE = Duty Cycle ( fraction, range: 0.0-1.0 ) "
CONSTANT DCYCLE = 0.338
" V1    = Input Voltage (Volts) "
CONSTANT V1IN   = 42.0
" ILOAD = Load Demand Current (Amperes) "
CONSTANT ILOAD = 0.0
" IDISCH, IHKEEP = Current Losses (Amperes)"
CONSTANT IDISCH 0.400, IHKEEP = 1.09
" Circuit Parameters "
" R3 = Transistor 3 ON Resistance (Ohm) "
CONSTANT R3 = 2.0E-3
" Input Filter "
" L30  = Inductance (Henry)"
CONSTANT L30  = 2.0E-6
" R30 = Resistance(Ohm), C30 = Capacitance (Farad) "
CONSTANT R30 = 50.0E-3, C30 = 20.0E-6
" Output Filter "
" L45=Inductance(Henry),R50=Resistance(Ohm), C50=Capacitance(Farad)"
CONSTANT L45 = 2.0E-6, R50 = 50.0E-3, C50 = 50.0E-6
" R52 = Output Resistance (Ohm) "
CONSTANT R52 = 13.4E-3
" Given Initial Conditions "
CONSTANT I1Z=0.0, IL45Z=0.0, VC30Z = 0.0, VC50Z = 0.0
" SWLDDC = Load Drop Switch: 0.0(off), 1.0(on) "
CONSTANT SWLDDC = 1.0
" TLDDC  = Battery Terminal Opening Time(sec) "
CONSTANT TLDDC  = 500.0E-6
" RLDDC  = Load Resistance(Ohms) "
CONSTANT RLDDC  = 0.1
                  " Initial Region Computations "
INITIAL
" TPER = PWM Switching Period (sec) "
TPER   = (1.0/FPWM)
" TPW1 = Transistor 1 ON Time or Pulse Width (sec) "
TPW1   = (DCYCLE*TPER)
" TPW2 = Transistor 1 OFF Time (sec) "
" TPW2 = Transistor 2 ON Time (sec) for Synchronous Rectification "
TPW2   = (1.0-DCYCLE)* TPER
" TS2  = Starting Time for Transistor 2 Pulse (sec) "
TS2    = TS1+TPW1
" Initialization of State Variables for Steady-State Operation "
END INITIAL
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                    " Dynamic and Derivative Region Computations "
DYNAMIC
 DERIVATIVE EQS
                    " Simulation Controls "
 ALGORITHM ISTART = 5, IRUN = 5
 CINTERVAL CI     = 0.5E-6
 NSTEPS    NST    = 200
 MINTERVAL HMINT = 1.0E-12
                    " V1    = Input Voltage "
 V1     =  V1IN*STEP(TS1,T)
                    " IR52 = Load Demand Current "
 IR52   =  ILOAD*STEP(TS1,T)
                    " DC to DC Buck Converter Operation "
 I1S     = (1.0/L30)*(V1-V3-R3*I1)
 I1      = INTEG(I1S,I1Z)
 IC30    = (I1-DCYCLE*IL45-IDISCH)
 VC30S   = (1.0/C30)*IC30
 VC30    = INTEG(VC30S,VC30Z)
 V3      = VC30+R30*IC30
 IC50    = (IL45-IR52-IHKEEP-IBB14-ILDDC)
 VC50S   = (1.0/C50)*IC50
 VC50    = INTEG(VC50S,VC50Z)
 V5      = VC50+R50*IC50
 IL45S   = (1.0/L45)*(DCYCLE*V3-V5)
 IL45    = INTEG(IL45S,IL45Z)
 V2      = V5-R52*IR52
         " Power Computations "
 " PWOUT = Power Output (Watts) "
 PWOUT = V2*IR52
 " PWLOSS  = Power Losses (Watts) "
 PWLOSS= R3*I1**2+V3*IDISCH + V5*IHKEEP + R52*IR52**2
 " PWIN = Power Input (Watts) "
 PWIN  = PWOUT +PWLOSS
 END DERIVATIVE
TERMT(T.GE.TFIN)
END DYNAMIC
                              " Terminal Region Computations "   "
TERMINAL
END TERMINAL
END PROGRAM
```